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Note that the times shown in the study plan overleaf do not include the time that you will need to answer questions on the DVD and the TMA, making use of the set book, watching the TV programme, attending sessions at your local or regional centre or reflecting on what you have learned and how you have learned it. Past students have also commented that *our* estimates of the times needed for the study of the DVD-multimedia activities are likely to be low.

Study Guide for Block 4

Block 4 involves the study of the living organisms that inhabit the Earth. We start with the question 'What is life?' and go on to investigate life at various levels — from the basic units of which organisms are made to the huge variety of living things that exist on our planet. Thus we will uncover the 'unity within diversity' of the block's title. On the way we look at how individual organisms survive and reproduce, and at how groups of organisms live together in an ecosystem. We discover how the immense diversity of life can be classified into groups of related organisms, and investigate one of the underlying reasons for the existence of these groups — the process of evolution.

Block 4 represents two weeks' work in the S103 *Study Calendar*. During these two weeks you will work with two DVD-multimedia activities and do two pieces of practical work. The first DVD-multimedia activity ('Ecological chains: finding the links') comprises almost the whole of Section 7. Similarly, almost the whole of Section 9 is devoted to the first part of another DVD-multimedia activity ('Galapagos: adaptation and evolution on islands'), which you will return to if you decide to study Block 9. Both of these activities are considerably longer than any of the DVD-multimedia activities in earlier blocks. It is therefore particularly important that you plan your study of them carefully, and Activity 1.1 helps you to do this.

During your study of Section 2, you will carry out a small investigation over a period of a few days on the fungal particles found in air. For this you will need a small can of cheap tomato soup, a rectangular container with transparent or translucent sides (e.g. an ice-cream tub), some cling-film and a ruler. In Section 8, you will be asked to find a holly bush or tree from which you can remove some leaves as part of a piece of practical work on an insect species that spends much of its adult life boring through holly leaves. This practical work relates mainly to this block. However, because much of the work must be carried out later in the course, you will complete it if you decide to study Block 9.

Many of the activities in the block focus on the scientific skill of classification and on the skills of communicating science using correct terminology and appropriate diagrams. You will be asked to classify organisms, to prepare your own glossary, to write short pieces of scientific text and to summarize information in the form of diagrams.

We recommend that you study the various sections of this block — including the DVD-multimedia activities — in the order in which they are presented, since several sections build on material covered in earlier sections. However, as with Block 3, if for some reason you are prevented from tackling a DVD-multimedia or practical activity at the recommended time, don't let this stop you from progressing through the book. Scan through the notes and comments for the activity in the *Study File for Block 4* to get an idea of its content, and continue with studying the book.

Our estimates of the study time likely to be required for each section or major activity are given in the study plan overleaf. The total directed study time for the block over the two weeks is 20 hours. Part of TMA 04 is associated with Block 4; the first activity in the block asks you to spend some time thinking about how and when you will tackle this assignment.

The S103 *Study Calendar* gives you the broadcast times of the relevant TV programme, 'A formidable foe'. We recommend that you watch this programme after you have studied Section 6.

You should begin your study of Block 4 by reading Section 1 of the book.

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5.1 DS

SUP 83603 8

4 Unity within diversity

All study times are in hours

Week	Sections of Book 4	Total study time	DVD-multimedia, DVD-video and practical activities
1	1 Introduction	$\frac{1}{4}$	
	2 What is life?	$1\frac{3}{4}$	$\frac{1}{2}$
	3 The cell: unity within diversity	$1\frac{1}{2}$	
	4 Diversity: the spice of life	$1\frac{3}{4}$	
	5 Biodiversity	1	
	6 Reproduction	$1\frac{1}{4}$	
2	7 Ecology: relationships between species	5	multimedia 5
	8 The biology of populations	$1\frac{3}{4}$	$\frac{1}{4}$
	9 Adaptation and evolution	2	multimedia 2
	10 Evolution through natural selection	$1\frac{1}{2}$	
	11 The evolution of clutch size in birds: a case study in natural selection	$1\frac{3}{4}$	
	12 Levels of explanation in biology	$\frac{1}{2}$	
	'A formidable foe', should be viewed at any time after you have completed Section 6.		

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Study File for Block 4

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Notes on activities

You should read through the notes for each activity before attempting it.

After completing an activity you should study the relevant comments in the next section of the Study File.

No estimate of time is given for activities which should take 10 minutes or less.

Activity 1.1 Planning ahead

As we indicated at the end of Block 3, from now on the basic planning of your study of each block will generally be left to you to think about on your own. We will, however, ask you to consider various additional factors from time to time, and in this activity we would like you to consider how you are going to include the DVD-multimedia activities and the assignment questions for this block in your study plans. We will also ask you to consider whether you need to set aside extra time for developing skills associated with using and grasping new terminology.

(a) The *DVD-multimedia activities* in this block require special planning because they are substantially longer than those in Blocks 2 and 3. We estimate that Activity 7.1 will require 5 hours and Activity 9.1 will require 2 hours, whereas the time estimate for the longest DVD-multimedia activity you have done so far was an hour and a quarter. You will probably wish to split your study of each of these activities over several sessions, and clearly these sessions will need to be at times when you can use your computer.

Spend a few minutes considering *when* you will aim to tackle each of the DVD-multimedia activities. Bear in mind that the *best* times to study each of these activities are when you have reached the point in the book where they are referred to, i.e. in Sections 7 and 9, but you may have to start them earlier or later if access to your computer dictates this. Also, think about your experience with earlier DVD-multimedia activities and, in particular, whether you have found that there is a maximum time that you can concentrate in front of the computer screen, and include that in your planning.

(b) The *TMA* for this block differs from those you have been accustomed to in the course so far, because it covers Block 5 as well as Block 4. You need to decide when you will aim to do the questions associated with Block 4, and to build this into your work plans.

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SUP 82832 2

5.1 DS

Your experience of completing the first full-length assignments in the course (TMAs 02 and 03 on Blocks 2 and 3) should have given you a good idea of the time that is required for an assignment. Were you surprised by how long you took to do it? Read through the TMA questions for Block 4 and try to make an estimate of how long they will take, and then build this estimate into your plans.

You will need to find a little time to look through the comments and feedback on TMAs 02 and 03 from your tutor, and you will find some advice on this in the 'General advice about S103 assignments: Part I' in *Assessment Booklet 1*. The advice there also refers to a helpful section about managing assignments in *SGSG* (Chapter 9, Section 6), and if you haven't read this, it would be worth setting aside 15 minutes to do so before starting on TMA 04.

(c) *Skills development* in this block emphasizes both comprehending the precise meaning of scientific terms and writing in a scientific style. How confident do you feel about your ability to familiarize yourself readily with new scientific terms, and about your ability to write a clear scientific account using such terminology? Do you want to allocate some time to studying sections of *SGSG* that are concerned with writing skills?

Activity 2.1 Investigating fungal particles in the air

(*The estimated time for this activity is 30 minutes (spread over several days).*)

Equipment

NON-KIT ITEMS
small can of cheap tomato soup
rectangular plastic container
cling-film
ruler or other measuring device

Aims

The aim of this investigation is to estimate the density of fungal particles in a room (e.g. the kitchen), by exposing an appropriate growth medium (tomato soup) to a known volume of air and then seeing how many fungi grow on it.

Introduction

Density, which tells us the number of things (or the mass of a substance) in a given volume, is normally expressed as number (or mass) per cubic metre. The basic idea of this investigation is to allow fungal particles in the air to settle on the tomato soup and then to estimate the density of particles in the air by counting the number of fungi growing on the surface of the soup. Since it would be very difficult to expose the soup to exactly 1 m^3 of air, our strategy is to expose the soup to a known (smaller) volume of air in the rectangular container and then use maths to work out the number of particles per cubic metre.

Task 1 Thinking about the design of the investigation

Amongst other things, you will need to think about how to make sure that a known volume of air is in contact with the soup, and that no fungal particles are introduced from elsewhere.

Spend a few minutes thinking about precisely how you will carry out this investigation using the equipment listed above. It may help you to think of questions such as:

- What size container do I need?
- Why was it suggested that a rectangular container be used rather than (say) a cylindrical one?
- How do I make sure that only air and soup are in the container at the start of the investigation?
- How do I make sure that nothing else gets inside the container once the investigation is under way?
- How do I measure the volume of air in the container?
- Where should I leave the container for the duration of the investigation?
- How long should I leave it ?
- How do I make sure that no-one disturbs it?
- What records should I keep of the investigation?
- What should I do with the container and its contents afterwards?

You should read the comments on Task 1 of this activity before proceeding to Task 2.

9am

9th April 2007

13.5cm x 13.5cm x 4.3cm

Practical procedure

Task 2 Setting up the experiment

Wash the container thoroughly and allow it to dry upside down. When it is dry, open the can of soup and quickly pour the contents into the container. Immediately cover the container with the cling-film. Label the container so that it is clear what it is and who is responsible for it; ensure that the label says 'NOT TO BE EATEN'. Record the date and time, and where the container is to be kept for the duration of the investigation. *Make sure that the container is kept out of reach of young children at all times.*

You need to calculate the volume of air between the surface of the soup and the cling-film. Measure the width and length of the container (these will be approximate measurements as the corners of the container are likely to be rounded). If you use a translucent container, you will be able to measure the distance from the surface of the soup to the cling-film from the outside. If you can't see the level of the soup through the side of the container, wait until the end of the experiment and then take the measurement after peeling back the cling-film a little before re-attaching it. You should not do this during the course of the investigation, as this would allow more fungal particles to enter.

Record your measurements, being careful to use the same unit for each one you make. Don't forget to note down which unit you used (e.g. cm).

Carefully place the container in a warm location where it won't be disturbed.

Task 3 Obtaining and recording the results

Without lifting the cling-film, inspect the surface of the soup every day or two. On each occasion count and record the number of separate areas of fungal growth you can see. You might also like to write a brief description of the fungal areas. Are there different types of fungus growing on the soup?

Data collection can cease once it is clear that the number of areas of fungal growth is no longer increasing between inspections.

For safety reasons, we recommend that the container and its entire contents be disposed of straightaway — without removing the cling-film — just as you would dispose of any other contaminated food. If you wish to keep the container, make sure that it is immediately washed extremely thoroughly.

Analysis of results

Since each area of growth probably represents one fungus which will have arisen from one fungal particle, you can now work out the density of fungal particles in the sample of air above the soup.

Task 4 Analysing your results

To find the volume of air, multiply your three measurements together. You are multiplying three lengths together, so your units will become cubic (e.g. cubic centimetres). To convert from cubic centimetres (cm^3) to cubic metres (m^3) divide by 10^6 (because there are 100 cm × 100 cm × 100 cm, or 10^6 cm^3, in 1 m^3).

You can write your result as 'so many fungal particles' per 'so many cubic metres', e.g. 6 fungal particles per 6.8×10^{-4} m^3.

However, it is more useful to know how many fungal particles there are in 1 m^3, so that your results can more readily be compared to those of other students.

In the example given above,

$$6 \text{ fungal particles per } 6.8 \times 10^{-4}\ m^3$$

$$= \frac{6 \text{ particles}}{6.8 \times 10^{-4}\ m^3}$$

$$= \frac{6}{6.8 \times 10^{-4}} \text{ particles per m}^3$$

$$= 8.8 \times 10^3 \text{ fungal particles m}^{-3}$$

So to find the density of fungal particles in the air, you divide the number of particles by the volume of air containing that number.

Calculate a value for the density of fungal particles measured in your experiment, and then write a conclusion to your investigation that includes this result.

The sample of air above the soup came from one particular location (e.g. the kitchen), so if you know the volume of air in that location, you could work out the total number of fungal particles in the air in that location.

Review

Task 5 Thinking critically about your results

The result obtained for this investigation relies on a number of assumptions. You might like to discuss these assumptions with other students or your tutor. Why, do you suppose, is the density of fungal particles obtained almost certainly an under-estimate of the true density?

Task 6 Thinking of possible further investigations

This investigation may have set you wondering what would happen if you tried a slightly different investigation. You may even be thinking of other experiments you would like to carry out, in order to investigate fungal particles more fully. Spend a few minutes thinking about what else you might like to find out — and how you would go about it. Try to formulate your thoughts as questions to be answered experimentally. Again, it would be valuable to discuss your thoughts with other students or your tutor. Note that, although we have referred to 'fungal particles', they are more correctly called 'fungal spores'.

Activity 2.2 Producing a glossary of biological terms

(*The estimated time for this activity is 1 hour (spread over the whole of the your study time for this block).*)

Constructing a *personal* glossary as you study can be a very useful learning technique for a number of reasons. First, pausing at the end of each section and asking yourself what new terms have been introduced will help you remember what the section was about. Second, thinking about definitions and writing them down in your own words will help you to remember them better. Third, your glossary will be a handy source of reference as you progress through the block; whenever you are unsure of the meaning of a term you have met before, you can refer to your personal glossary.

There are a number of different ways of laying out your glossary. In deciding which way to adopt, you may wish to bear the following considerations in mind.

- The glossary will be easier to use if arranged, at least approximately, in alphabetical order.
- You don't know in advance how many words there will be altogether.
- You may want the glossary to be 'portable', so that you can have it with you whenever and wherever you are studying.

Possible solutions include the following:

- a small notebook, divided by letter of the alphabet
- an address book (already divided by letter)
- a loose-leaf binder
- file cards
- a database package on your computer.

Note that there is a trade-off between, on the one hand, perfect alphabetical order and hence ease of searching (in which the computer easily wins) and, on the other hand, portability (where the computer loses unless you are fortunate enough to have a laptop or electronic personal organizer). The choice of physical medium is entirely up to you.

Begin a glossary for Block 4 by writing your *own* definitions of the following terms: autotroph, heterotroph, generation time, life cycle, metabolism, reproduction. Include any other terms that were new to you or used in a new way (e.g. respiration, carnivore, fungi). Add further terms as you continue to study the block. This activity is best done reflectively so that you are recalling the terms and remembering the context in which they were used.

Activity 3.1 Analysing and improving a description of the cell cycle

(*You should spend about 15 minutes on this activity.*)

Read the following short description of the cell cycle.

> The cell cycle, which takes different amounts of time, consists of growth and division. Growth takes place twice. These are called growth 1 and growth 2. There are also two parts to division. These are mitosis and cell division. Also there is replication in the middle of intophase.

(a) List any inaccuracies contained in the description.

(b) Jot down any ways in which the description is less clear than it might be.

(c) Have a go at producing a better description of the cell cycle in not more than about twice the number of words used in the original description.

Activity 3.2 Drawing a diagram of mitosis

(*You should spend about 15 minutes on this activity.*)

In this activity you will draw a diagram to help you to remember what happens in the various phases of mitosis. We have given you guidance about drawing diagrams in previous blocks, and there are more ideas in *SGSG* Chapter 2 (Sections 2.1 and 3.1 are particularly useful). However, on this occasion, we leave the choice of type of diagram entirely up to you.

Since mitosis is an important concept, which you will need to remember in some detail, we suggest that you close the book before beginning this activity. Draw a diagram which helps *you* to visualize the order of the different phases of mitosis and what occurs in each phase. Then look at the relevant pages of the book, amend your diagram to ensure that it is accurate, and add anything you think might be useful. Two possible diagrams are given in the comments on this activity. However, it doesn't matter if your diagram is very different, so long as it helps you.

What else could you do in order to help you to remember the order in which the phases of mitosis occur?

Activity 4.1 Devising a classification scheme for living things

Classifying living organisms depends on recognizing the similarities and differences between them. Similarities allow us to group organisms together; differences allow us to distinguish one group from another. This activity asks you to classify a number of living organisms into groups based on recognition of the features that they have in common.

(a) Consider the following, reasonably familiar, animals: tiger, salmon, blue tit, snail, ladybird, lobster, donkey, seal, jellyfish, whelk, peafowl, frog, spider. Spend a couple of minutes thinking about the features you might use as a basis for identifying similarities or differences between them, which could be used to classify these animals into *natural* groups.

(b) Table 4.1.1 lists these 13 animals. Along the top of the table are a number of features which some or all of these animals possess. For each animal, put a tick in the columns where the animal has the feature listed.

(c) When you have completed the table, group the organisms into a natural classification based on the features in the table that they share.

Table 4.1.1 Characteristics of some animals.

	Internal skeleton	Jointed external skeleton	No obvious hard parts	Simple external shell	Ability to move around
tiger (*Panthera tigris*)	✓				✓
Atlantic salmon (*Salmo salar*)	✓				✓
blue tit (*Parus caeruleus*)	✓				✓
garden snail (*Helix aspersa*)				✓	✓
two-spot ladybird (*Adalia bipunctata*)		✓			✓
lobster (*Homarus vulgaris*)		✓			✓
donkey (*Equus asinus*)	✓				✓
elephant seal (*Mirounga angustirostris*)	✓				✓
Portuguese man-o'-war jellyfish (*Physalia physalia*)			✓		✓
whelk (*Buccinum undatum*)				✓	✓
peafowl (*Pavo cristatus*)	✓				✓
strawberry frog (*Dendrobates pumilio*)	✓				✓
water spider (*Argyroneta aquatica*)		✓			✓

Activity 4.2 Working with a scheme of biological classification

Primates is one of 15 orders within the class Mammalia. This order is generally divided into two suborders: the prosimians (i.e. the lemurs, lorises, bushbabies and tarsiers) and the simians (i.e. the New World monkeys, the Old World monkeys, the apes and humans). Each of the two suborders contains six living families. Table 4.2.1 summarizes this information, names the 12 primate families and mentions some representative primate species.

On the basis of the information contained in Table 4.2.1, answer the following questions:

(a) What is the gorilla's scientific label? Name the gorilla's class, order and family.

(b) What is the chimpanzee's scientific label?

(c) In which of the following pairs are the two named species most closely related, and in which are they least closely related? In each case, give your reason.

(i) The aye-aye and the siamang.

(ii) The common marmoset and the Japanese macaque.

(iii) The red howler monkey and the golden lion tamarin.

(iv) The slender loris and the lesser bushbaby.

(d) To which family or families is the family Hominidae most closely related?

(e) Produce a diagram similar to Figure 4.9 in Block 4 for humans.

Table 4.2.1 Classification of living families within the order Primates.

order Primates			
suborder Prosimii (prosimians)		suborder Anthropoidea (simians)	
family	example(s)	family	example(s)
Cheirogaleidae (mouse and dwarf lemurs)	mouse lemur species (*Microcebus*)	Cebidae (true New World monkeys)	red howler monkey (*Alouatta seniculus*)
Lemuridae (other lemurs)	mongoose lemur (*Lemur mongoz*)	Callitrichidae (marmosets and tamarins, also of the New World)	common marmoset (*Callithrix jacchus*) golden lion tamarin (*Leontopithecus rosalia*)
Indridae (indri group)	indri species (*Indri*) Verreaux's sifaka (*Propithecus verreauxi*)	Cercopithecidae (Old World monkeys)	Japanese macaque (*Macaca fuscata*)
Daubentoniidae (includes only one species: the aye-aye)	aye-aye (*Daubentonia madagascariensis*)	Hylobatidae (gibbons)	siamang (*Hylobates syndactylus*)
Lorisidae (lorises and bushbabies)	slender loris (*Loris tardigradus*) lesser bushbaby (*Galago senegalensis*)	Pongidae (great apes)	orang-utan (*Pongo pygmaeus*) gorilla (*Gorilla gorilla*) common chimpanzee (*Pan troglodytes*) pygmy chimpanzee or bonobo (*Pan paniscus*)
Tarsidae (tarsiers)	Borneo tarsier (*Tarsius bancanus*)	Hominidae (humans)	humans (*Homo sapiens*)

Activity 5.1 Extracting information from a scientific article

In the mid-1990s there was considerable controversy surrounding Shell UK's plan to dispose of Brent Spar, a redundant oil production platform, at sea. The article reproduced in Figure 5.1.1, 'Rockall mud richer than rainforest', appeared in the weekly science magazine *New Scientist* at about that time.

We will ask you to read the article and then answer a number of questions. These questions require you to extract information on specific aspects of biodiversity from the article. This is similar to what you did in Block 3, Activity 7.1, when you studied the newspaper report of the 1995 Kobe earthquake and identified key points from it. On that occasion you were advised to highlight the relevant points as you read the article. Highlighting would again be a good way of indicating the relevant parts of the Rockall mud article, but on this occasion you need first to decide what you are looking for. You may want to skim-read the article before doing anything else, but you would be well advised to read the questions carefully and to make sure that you know what you are being asked *before* you read the article in detail. Then you will know what to highlight.

The questions are:

(a) What three beliefs about biodiversity does the article claim are widely held?

(b) What recent finding may undermine all three of these beliefs?

(c) What are the implications of this finding for estimates of global biodiversity?

Rockall mud richer than rainforest

Fred Pearce

THE Rockall Trough off western Scotland, where Shell wanted to dump the Brent Spar, is "among the richest environments in the whole world", says John Lambshead of the Natural History Museum in London. The seabed dump site, which energy minister Tim Eggar claimed last week contained "just a few worms", may in fact be home to more species than the richest rainforest, even if most of them are microscopic mud-dwelling nematodes.

Speaking at the British Association's Annual Festival of Science in Newcastle upon Tyne this week, Lambshead contradicted another speaker, who claimed that dumping waste at sea would not damage valuable biological resources.

Research into nematodes is causing biologists to radically revise their estimates of the number of species on the planet. There may be 100 million species of nematodes, says Lambshead, who is a specialist in these worms. Most inhabit the sediments of the deep oceans. They may make up three-quarters of all the planet's species, previously estimated to number about 30 million. And the Rockall Trough is one of the places where they congregate in greatest profusion and variety.

In a paper to be published later this year, Lambshead and Guy Boucher of France's national research agency, the CNRS, point out that the slopes that plunge from the edge of the continental shelves, known as bathyal regions, contain a greater range of species than anywhere else on land or sea. An analysis of sediment from 17 seabed sites — from European estuaries to the Great Barrier Reef in Australia and the deep Atlantic Ocean — found that the bathyal region of the Rockall Trough has more species than any other area so far measured. Bathyal regions "have much greater biodiversity than coral reefs, which are often said to be the rainforests of the oceans" says Lambshead. "Coral reefs have more vertebrates, but much less overall biodiversity."

Gordon Patterson, also of the Natural History Museum, says that in 16 sediment cores taken from the Rockall Trough area, containing 4 cubic metres of material, he found 325 species of a single group of worms he was studying, and numerous other species he never bothered to count. "By anybody's standards, that is high biodiversity", he says.

Boucher and Lambshead argue that the conventional view that marine biodiversity declines with depth is wrong. Maximum biodiversity occurs in bathyal regions, between 1000 and 3000 metres down, they say. Nor does biodiversity in the deep ocean decrease away from the tropics, as it does on land. The Rockall Trough has significantly greater diversity than the San Diego Trough, off California, for instance.

Like other researchers with detailed knowledge of the ocean bed in the Rockall Trough, Lambshead claims he was not contacted by Shell's consultants during their three-year environmental impact study of the Brent Spar dumping ground (*This Week*, 26 August). "When I read that Shell claimed the area where they planned to dump the Brent Spar was a quiet area, low in biodiversity, I was staggered. It was 50 years out of date", he says.

Lambshead's presentation to the BA contradicts another paper, by Martin Angel of the Institute of Oceanographic Sciences in Surrey. In discussing the opportunities for waste disposal in the deep sea, Angel argues that environmentalists should not be allowed to shut off this option to deal with "large-bulk low-toxicity wastes." Angel claims that "there are almost without exception no living resources worth exploiting" on the deep seafloor.

"There may not be much deep-sea fishing, but what about genetic resources?" Lambshead counters. "After all we don't eat much meat from the rainforest, but drug companies think the rainforests contain huge genetic resources. The same may be true of the deep ocean."

Angel also argues in his paper that local dumping would cause "no impact on biodiversity ... because the distribution of species are ocean basin in scale." Lambshead says there is not enough evidence to support this view, especially when it comes to the smaller animals. "We know far too little about them", he says.

Lambshead calls for more research into nematodes. So far, he says, their contribution to global biodiversity has gone unrecognised because there are only about twenty active marine nematode taxonomists in the world. They describe about 10 new species a year, and so far only 4000 marine species have been described.

But that doesn't mean the species aren't there. Methods routinely used to estimate the number of species on land suggest that there are many tens of millions of marine species, and up to 100 million nematodes alone, he says. Nematodes, says Lambshead, rank with insects and fungi among the most species-diverse groups of organisms on Earth. □

Figure 5.1.1 From *New Scientist*, 16 September 1995.

Activity 6.1 Drawing a diagram

(*You should spend about 15 minutes on this activity*)

As in Activity 3.2, it does not matter what sort of diagram you draw to show the sequence of events in sexual reproduction, provided that it helps you to understand and remember. Start by looking back through Section 6.2, making notes if necessary. Then draw a diagram to show the order in which the different events in sexual reproduction occur

Activity 6.2 Comparing sexual and asexual reproduction

(*You should spend about 15 minutes on this activity*)

Draw up a table which compares and contrasts sexual and asexual reproduction. (Recall from Block 3, Activity 14.1, the meanings of 'comparing' and 'contrasting')

Again, it is a good idea to try this with the book closed in order to discover what you can remember. Start your table with the more obvious similarities and differences. However, don't forget to think about other features (e.g. differences between the two processes at the cellular level) before you finish.

Activity 7.1 Ecological chains: finding the links

multimedia

(*The estimated time for this activity is 5 hours*)

This is the longest DVD-multimedia activity in the course, so before you start it would be worth recalling what you have learned about the best ways of studying DVD-multimedia activities. In Activity 18.1 at the end of Block 3 we asked you to reflect on your experience with the seven DVD-multimedia activities in that block, and you should look back at any advice that you noted down then, and think about how you will apply it to this activity

As the name 'Ecological chains: finding the links' suggests, this activity is an introduction to key ecological ideas and techniques, based on the ecology of a temperate woodland which is dominated by oak trees. The activity introduces the ideas of 'producers' and 'consumers' within an ecosystem, and examines the links between different organisms which form food chains and more complex food webs. These links can be viewed in terms of the flow of energy through an ecosystem.

A variety of new terms will be introduced, some of which are not covered elsewhere in the block, and you will need to note these in your personal glossary (they are also in the course *Glossary*). Among these new terms are 'gross primary productivity' and 'net primary productivity'; note that you may see these referred to elsewhere as gross and net primary *production*. Either word is acceptable, so you might choose to note both alternatives in your personal glossary.

The whole activity is intended to take about five hours to complete. As the study time for this activity is much longer than any DVD-multimedia activity you have so far encountered, we offer a few tips on working through the activity

Finding your way around

There are seven sections to this DVD-multimedia activity and you'll find descriptions of each section under 'Aims and Objectives' in the menu. When you have completed a section of the activity you will be presented with a summary of the section, which, if you have a printer, you can print out to incorporate in your Study File. Alternatively, you may like to write your own summary notes based on each section summary. You may also want to print out a few other important screens. If there isn't a 'Print' button on the screen you are interested in, you can usually obtain a printout by pressing the 'Print Screen' key on your computer keyboard while holding down the 'Alt' key. This will place a copy of the screen onto the computer's clipboard. The contents of the clipboard can now be pasted into a new document, which you can print in the usual way.

You are strongly advised to study the material in the order that it is presented. Many of the ideas that come up later on are based on concepts you will have learned in earlier sections. You will want to spend some time familiarizing yourself with the oak wood ecosystem by working through the first two sections of the activity. However, *you will need to focus your attention fairly quickly on the main topics* (e.g. food chains, food webs, trophic levels, energy flow through an ecosystem) *if you are to complete the activity in the recommended time.*

Using the field guides

Most of the species that are referred to in the activity have their own 'field guides'. These give you a picture of the species, some data, and a 'resource file' of further information. Much of this information is required to complete the exercises, and will be available to you when you need it. Mixed in with the information that is essential for the exercises are other pieces of information which will help you to get a feel for the diversity of species in a woodland. Spring is one of the most exciting times of the year in a wood, and hopefully you'll be spurred on to visit one near you, and work out how many pairs of sparrowhawks it would support.

Summary cards

At the end of each section there is a 'card' which summarizes the section you have just finished. In addition this allows you direct access to the field guides and the resources (video clips, photos, data, etc.) which were available to you in that section.

Using the woodland landscapes

In Sections 1, 2 and 6 of the activity there are woodland landscapes which you can move around. Within these landscapes there are organisms which you can inspect. A double click on the organism will bring up the appropriate field guide for that species. Some of the organisms are quite hard to locate. You will know when you have found one because the cursor will change from a target shape to a hand holding the target. The name of the species will appear in the box below. If you are pressed for time, or quickly want to see what is there, the '*show hotspots*' button will put a little box around the species which you need to look at.

There are a few unlikely species in the landscape — we've had to cheat a little to get the mix of animals into a single daylight scene. You would be lucky to see a badger in the middle of the day, even lurking in the undergrowth like ours! Similarly if you saw a mole out in the sunshine it would probably be ill, or under attack. Artificially placing all the animals in the woodland landscape has also given rise to some scale problems. The gall wasp on the oak tree appears to be about 50 times its actual size! Check the field guides to get a true sense of size and scale

Organizing your study time

The estimated study time for each section of the activity is as follows:

Section 1 Introduction to an oak woodland: *20 minutes*
Section 2 A sparrowhawk's eye view: *30 minutes*
Section 3 How much food to raise a brood?: *45 minutes*
Section 4 Energy flow: *45 minutes*
Section 5 Getting the timing right: *45 minutes*
Section 6 Food webs: *1 hour*
Section 7 Pulling it all together: *45 minutes*

It is very important that you do not spend longer on Sections 1 and 2 than suggested above, at the expense of skimping or omitting the far more important later sections. In Section 6, we strongly recommend that you go straight on to answer questions on *our* version of the food web. However, if you have sufficient time available, it is interesting to try to build up your own version of the food web either directly from the woodland landscape or from the complete species list that you will find if you press the 'Field Guide' button under 'summaries'.

There is only one point (in section 6) where you will need pencil and paper to complete the on-screen tasks, though you will need to keep notes on the whole activity as you go along. Elsewhere you can make all the calculations or find out the necessary information using only the computer. But studying at a computer for a long time can be uncomfortable, and we recommend you don't spend more than about an hour in front of the computer screen without taking a break and doing something else. None of the sections should take more than an hour, so plan to take a break of at least 10 minutes (have a cup of coffee, read the newspaper, go for a run!) after each one, if possible. You do not need to complete the whole activity in one day, so you may find it convenient to stop after one or two hours (the computer will automatically save your progress) and then come back another day Keep a note of how long it takes to complete each section. Don't worry if you are taking a little bit more, or a little less than the estimated time. Each section of the activity has a different set of tasks and you may find that it takes you less time to tackle some, and more for others.

Notes on this activity

You may like to know that an overall summary of material covered in this DVD-multimedia activity can be found in the *Comments on activities* section of this Study File. Together with any summaries and other screens that you may have printed, and any notes you made while running the activity, this summary should enable you to revise this material without having to work through the entire activity again.

'Ecological chains: finding the links' is on the Block 4 DVD. To start this activity, you need to open the DVD Multimedia Guide on your computer, and click on the 'Ecological chains' button in the Block 4 folder. You should start this activity now.

Activity 7.2 The correct use of terminology

(*The estimated time for this activity is 30 minutes.*)

Write an account (of about 300 words) of the flow of energy through an ecosystem. Your account should include, and show a good understanding of, the following terms (some of which you may need to use more than once and some of which you may wish to use in alternative forms, e.g. autotrophic rather than autotroph):

assimilation	ecosystem	heterotroph
autotroph	faeces	net primary productivity
biomass	food chain	photosynthesis
carnivore	food web	respiration
decomposer	gross primary productivity	solar energy
detritivore	herbivore	trophic level

As you have compiled your glossary while studying this block, you will have realized that many scientific words and phrases have a very precise meaning. The glossary-building has emphasized the importance of understanding this meaning. Now we are asking you to demonstrate your understanding by using new words and phrases correctly in a piece of writing. We suggest that you follow the five steps outlined below.

1 You need to plan your piece of writing. You may need to look back at your notes from Activity 7.1 and also from previous sections. Put your ideas into a logical order.

2 You need to make sure that you understand the meaning of the terms that you are expected to use. Look them up in your glossary. Where in your explanation do you think that each term will fit? Remember that you can use each word or phrase more than once. Do any of the required terms not fit comfortably into your plan? This could be because you've missed something from your plan or because you've not properly understood the term.

3 You need to write out the answer. Remember to be as precise as possible in your use of words. This is nothing more than an extension of the clarity and conciseness which was encouraged in Block 1.

4 You should read over your answer. Does the overall meaning seem clear? Do you think that you have used each of the new terms in the correct way? Does your answer have a clear structure?

5 Finally, compare your answer with the one given in the comments on this activity.

Activity 8.1 Quantifying mortality factors in the holly leaf miner (Part 1)

(*The estimated time for this activity is 20 minutes (not including the time spent looking for a holly bush).*)

There are two tasks in this activity. The first comprises some preliminary practical work that you need to do *now* in preparation for Part 2 of this activity, which you will carry out if you decide to study Block 9. The second is a 'thought experiment', intended to help develop your skills at designing investigations; as such, it builds upon Task 1 of Activity 2.1.

Task 1 Preparation for Part 2 of the practical work

Find a holly bush or tree (it doesn't matter which, so long as you can reach some of its branches) that you can conveniently visit, and from which you can legally remove some leaves later in the course, if you are studying Block 9. The precise location of the holly (e.g. in the depths of the country or next to a busy road) doesn't usually matter for the purposes of this investigation. Have a look at some of the leaves without removing them from the plant. Have some of them been mined (as in Figure 8 5 in the book)? Predation of holly leaf miners by blue tits results in a distinctive triangular tear in the mine (Figure 8.1.1). Can you identify any leaves that show evidence of blue tit predation?

If you haven't got access to suitable holly - or you can't find any mined leaves on the plants available to you — it is very important that you seek your tutor's advice at this stage, rather than forgetting about the problem until you are just about to carry out Part 2 of the investigation

You might like to return to the holly in late May to see the adult flies, and it would be worth making a note of this in your diary. The tiny flies (only about 2.5 mm long) are black with a small white spot on each side of the body. They can often be seen perched on the very new holly leaves at the ends of branches

Figure 8.1.1 A holly leaf mine predated by a blue tit. (Two triangular tears are visible.)

Task 2 Thinking about the design of investigations

In Part 2 of this investigation you will be asked to collect 40 mined leaves at random for detailed examination. The leaves must be collected at random because you will be carrying out a statistical analysis in Part 2; for the results of your analysis to be valid, you need to be sure that your sample is a true reflection of all the leaves on the tree. So what does 'at random' mean in this context? How could you set about harvesting the leaves 'at random'?

In order to help you think about these issues, we suggest you spend a few minutes considering how you would set about trying to answer questions (a)–(c) below.

(a) What percentage of leaves on your holly have been mined?

(b) What percentage of the mined leaves on your holly have suffered blue tit predation?

(c) Do these percentages differ in different parts of the holly (e.g. close to the ground compared to higher up, on the north side compared to the south side of the plant, on the windward rather than the sheltered side)?

When you have thought about the issues that might arise if you were to try to answer these questions practically, read the comments on this activity. Of course, you could also investigate the questions practically — either now or later — if you have time

The main practical procedure for the holly leaf miner investigation is in Part 2 of this activity, which you will carry out if you study Block 9

Activity 9.1 Galapagos: adaptation and evolution on islands (Part 1)

multimedia

(*The estimated time for this activity is 2 hours.*)

This activity involves the study of the first part of the DVD-multimedia activity 'Galapagos: adaptation and evolution on islands'.

Charles Darwin visited the Galapagos Islands during his five-year voyage in the *Beagle*, a voyage that convinced him that species change over time. While in the Galapagos, Darwin collected specimens of a group of bird species that have since become famous as 'Darwin's finches'. This DVD-multimedia activity allows you to follow in Darwin's footsteps and 'visit' the islands, making your own observations of the various animals and plants found there. You will carry out a series of tasks that will allow you to explore the concept of adaptation, and enable you to recognize the relationships between the appearance of an organism and its lifestyle, habitat and diet. The tasks will involve you in collecting information, answering questions and working through various exercises.

This activity is in three parts, entitled respectively *Adaptation*, *Evolution in Real Time*, and *Species and Speciation*. In this block you should study only the first part (*Adaptation*). You will return to the DVD to study the second and third parts (*Evolution in Real Time* and *Species and Speciation*) if you decide to study Block 9.

Studying *Adaptation* should take about 2 hours. As with Activity 7.1, you may wish to split your study over more than one session. When you reach the end of *Adaptation*, you should return to the comments at the end of the Study File.

'Galapagos: adaptation and evolution on islands' is on the Block 4 DVD. For Block 4 you should only study the first part of this DVD-multimedia activity. You should start this activity now.

Activity 11.1 Estimating relative fitness from life history data

(*The estimated time for this activity is 20 minutes.*)

Table 11.1.1 presents hypothetical (but realistic) data for ten female great tits that have survived to breed at the age of one year old. These data therefore ignore the majority of females in this cohort, who will have died in the previous winter (Figure 11.2, Block 4).

(a) Complete column 10 ('Total number of fledglings') in Table 11.1.1 by adding up, for each bird, the total number of fledglings that they produced in their lifetime. (Birds 4 and 6 did not survive to a fourth breeding season.)

(b) Calculate the relative fitness of each bird to 3 decimal places and enter it in column 11 ('Relative fitness of bird') of Table 11.1.1. First, assign the bird that leaves the most fledglings a value of 1.000. Then calculate the relative fitness of all the other birds by dividing their number of fledglings in column 10 by the number for the bird you have just identified.

Table 11.1.1 Measures of reproductive success and fitness for a hypothetical population of 10 female great tits which survived their first winter (Winter 1).

Bird	Breeding success in Year 1		Winter 2	Breeding success in Year 2		Winter 3	Breeding success in Year 3		Total no. of fledglings	Relative fitness of bird
	No. of eggs	No. of fledglings		No. of eggs	No. of fledglings		No. of eggs	No. of fledglings		
1	14	3	dies	–	–	–	–	–		
2	15	2	survives	16	3	dies	–	–		
3	16	4	dies	–	–	–	–	–		
4	10	2	survives	12	3	survives	11	3		
5	17	4	dies	–	–	–		–		
6	11	3	survives	12	2	survives	12	1		
7	12	3	survives	14	2	dies	–	–		
8	14	4	dies	–	–		–	–		
9	12	0	dies		–	–	–			
10	16	3	survives	17	4	dies		–		

Before going any further, compare your figures in columns 10 and 11 of Table 11.1.1 with those in the comments for this activity and make any corrections that are necessary.

(c) How many components of fitness are there in the completed Table 11.1.1? What are they?

(d) Some birds survived long enough to breed once, some twice, some three times. Is survival a good indicator of relative fitness?

(e) There is quite a lot of variation in clutch size. Is clutch size in year 1 (when all ten birds were alive) a good indicator of their relative fitness?

(f) Do the values in column 11 reflect the true relative fitness of the ten birds?

Activity 11.2 Explaining the concept of a trade-off

(*The estimated time for this activity is 15 minutes.*)

This activity is in two parts.

(a) Write down as many of the factors that influence clutch size as you can remember. As in Activities 3.2 and 6.2, try to do this with the book closed, to discover what you have learned. The book identifies eight such factors but, as some of them are mentioned only in passing, your list will probably be shorter. If you have difficulty in remembering more than one or two factors, look back at the text, or look at the list in the comments on this part of this activity before proceeding.

(b) The concept of trade-offs in biology was introduced in Section 8 and several examples have been given since then. This part of the activity requires you to explain the concept of a trade-off in the context of clutch size. Think about your understanding of the term. You may want to look it up in your personal glossary or think about the use of the term in everyday life. Looking back at the examples given in the book might also help.

Now choose one of the factors influencing clutch size which you think illustrates the principle of a trade-off particularly well and have a go at explaining why it is a trade-off. Your answer need not be very long (certainly shorter than 100 words).

Note that in this activity you are being asked to illustrate a *general* term with a *specific* example.

Activity 12.1 Reviewing your study of Block 4: using scientific language

(*You should spend about 25 minutes on this activity.*)

A number of activities in this block focused on improving your understanding and usage of scientific terms, and there were three main aspects to this. The first aspect was the construction of a glossary of important terms as you met them in the block. The second was a technique of explaining or using terms or producing a diagram or table from memory, and then checking what you had produced against the course material, so that you could correct it, or add to it. The third aspect was using these new terms correctly and appropriately in scientific writing, and you probably found that this was easier because your understanding of the terms had been strengthened by the first two aspects.

(a) Think about the glossary you built up in the on-going Activity 2.2. How useful did you find writing your own definitions, or descriptions? Did using your own words help you to *understand* the terms? Did this help you to *remember* those terms? Do you use any other techniques to help you understand and remember new scientific terms?

If you now look at your glossary, and cover up the definitions you wrote, how many of them can you remember? What is triggering your memory each time?

Of course, when you look at your glossary definitions, you may want to change some of them in the light of further learning during your study of the block. Do you notice any difference between those you wrote early in this block, and those you wrote later on? Have your definitions improved? In order to assess this, you might like to compare a few of your definitions with those in the course *Glossary*.

(b) When you want to learn something, how useful do you find the technique of reading the relevant text, closing the book, answering a question from memory and then using the book to check your answer? Did you find that producing an answer to a question reinforced your learning of important concepts?

(c) The main activity in this block that involved you in writing in a scientific style, using scientific terminology appropriately, was Activity 7.2. Look back at this, and look again

at the article 'Rockall mud richer than rainforest' in Activity 5.1. Highlight some of the scientific terms and look at how they are used in their setting. Can you see any differences between your use of terminology and that of the professional writer in the article? What else do you notice when you compare your own style of writing with the style of the article? Make a note of any advice you can give yourself about how to set about a piece of writing and of any tips you have for achieving a style which another scientist will find easy to follow.

You should complete your study of Block 4 by trying the questions on the Block 4 DVD.

Acknowledgements

Grateful acknowledgement is made to the following sources for permission to reproduce material in this study file

Figure 5.1.1: Pearce, F. (1995) 'Rockall mud richer than rainforest', *New Scientist*, 16 September 1995, © Reed Business Information Ltd.; *Figure 8.1.1*: Dr Marion Hall.

Comments on activities

Activity 1.1

(a) We will provide advice about *how* you might study the DVD-multimedia activities in the notes for those activities, and at this stage it is only important that you have planned appropriate chunks of time for them. As with studying books, different students have different concentration spans when studying DVD-multimedia activities, and it is important for you to be aware of how long you can study effectively at a stretch. Of course, this will be partly dependent on the nature of the material you are studying, and how interesting you find it. It is worth developing the habit of asking yourself at fairly frequent intervals 'What have I learnt in the last 10 minutes?' If you find it difficult to answer, it may indicate that your attention is wandering and that you need to take a break!

(b) As we said in the 'General advice about S103 assignments: Part 1', we recommend that you plan to tackle the Block 4 questions as soon as possible after you have studied the relevant parts of the block. The course material will then be fresh in your mind. You can always review your answer and make minor changes if necessary, before submitting the assignment.

Most students are really surprised at how long they take to complete a TMA — sometimes it is far more than the allocated time. There are various reasons for this. Some students are perfectionists, and they spend so long polishing their work that they fall behind schedule. Others are apprehensive about critical comments from their tutor (usually before they have got to know them!), and do not want to submit what they feel may not be good enough. Some find that although they thought they had understood all the information in the block, they can't decide where to begin when answering the TMA questions. However, it is important that you don't spend so long working on the assignment questions that you fall behind with the course. Keep in mind the law of diminishing returns: you may be able to get 50% of the marks for an answer by working on it for half an hour; another half hour may get you an extra 25%, a further half an hour an extra 12%, and so on. At a certain point it is more important to move on to the next part of the course rather than trying to improve your answer a bit more.

(c) There is a range of different activities in this block to help you become more comfortable with new scientific terminology and use it effectively in scientific writing. If this is an area that you think that you need to work on, we recommend that you read *SGSG* Chapter 9, Section 4 about using scientific terminology and *SGSG* Chapter 9, Section 5 about writing.

Activity 2.1

Task 1

Here are our responses to the questions posed.

What size container do I need?

As long as the container has room for the contents of the soup can and approximately the same volume of air or more, its size is not critical.

Why was it suggested that a rectangular container be used rather than (say) a cylindrical one?

There is nothing wrong with using a cylindrical container. It is just that the maths involved in working out the volume of the air is easier with a rectangular container than with a cylindrical one. An empty rectangular ice-cream tub would be ideal for the investigation.

How do I make sure that only air and soup are in the container at the start of the investigation?

The container must be as clean as possible. After washing and rinsing it, it is best to leave it to dry in the air, since contamination can be introduced from cloths used for drying. In fact, it would be better if the container were left upside down as it dries to reduce the chance of fungal particles settling on the inside while it is drying.

How do I make sure that nothing else gets in once the investigation is under way?

Clearly, the container needs to be covered during the investigation: cling-film is probably the best option. The advantage of using cling-film — rather than the container's own lid — is that you can see what is happening during the course of the investigation without having to lift the lid, which might introduce further contamination.

How do I measure the volume of air in the container?

You are going to have to measure the volume of air above the soup without disturbing the experimental set-up. It is easy to find the length and width of the container with a ruler, but how do you measure its depth? It is a good idea to use a translucent container if possible, so that you can see the level of the soup from the outside.

Where should I leave the container for the duration of the investigation?

The fungi are likely to grow faster if the container is left somewhere reasonably warm. Since it doesn't matter whether the container is kept in the light or the dark, a warm airing cupboard may be ideal.

How long should I leave it for?

This is a difficult one to answer at this stage. However, if cling-film is used and the container can be inspected (say) daily, then perhaps you don't have to decide before the investigation begins.

How do I make sure that no-one disturbs it?

Besides putting the container in a safe place (e.g. out of reach of young children), you should label it so that it is clear what it is and who is responsible for it. (Although this may be obvious at home, it is good scientific practice to label all experiments in this way.)

What records should I keep of the investigation?

You should certainly record the date and time when you started the investigation, and the location and conditions of the place where the container is to be kept during the investigation. You will presumably also want to record the date and time of each occasion when you inspected the container subsequently, as well as the number of fungi seen growing on the soup on each occasion and possibly a brief description of them.

What should I do with the container and its contents afterwards?

Although any fungi growing on the soup will have grown from fungal particles that were already floating in the air of your kitchen, we recommend that you dispose of the container and its entire contents without ever having lifted the cling-film. It is for this reason that we suggested that an ice-cream tub would be ideal, rather than a plastic lunch box that you would probably wish to keep.

You should now proceed to Task 2

There are no comments on Tasks 2 and 3.

Task 4

A typical conclusion for this experiment would be

> *Conclusion*: I measured the density of fungal particles in my kitchen to be 5.2×10^3 particles m^{-3}.

Of course, your value might be very different from the one quoted here; the density of fungal particles may be affected by factors such as which room you carried out the experiment in, whether you had a door or window open, and how recently you had cleaned the room!

Task 5

If two fungal particles were to land on more-or-less the same spot on the soup's surface, you might count the fungi they subsequently produce as one rather than two. Also, conditions in the container may not have been suitable for growth of all the fungal particles that settled on the soup, while some fungal particles might take longer to start growing than the number of days allowed. Finally, it is possible that some of the fungal particles in the air above the soup became permanently attached to the cling-film as a result of static electricity generated as you removed it from the roll.

Task 6

The list of possible further investigations is as long as your imagination allows. You might have thought of the following questions, which have been grouped into various categories. For each question you might like to try to think of an experiment you could carry out to answer the question.

'What if' type questions:

- What would happen if I used different soup, cottage cheese, etc.?
- What would happen if I worked in a different room, outside, at a different time of year, etc.?
- Would it make any difference if I boiled the soup first?
- Would more, or different, kinds of fungi grow if the container were left longer?

'How' type questions:

- How do fungal particles get into the air?
- What conditions do fungi require to grow?
- How can one stop fungal particles from growing on food?
- If one can't, does it matter?
- How can fungal particles be killed?

'Cross-checking' type questions:

- If I were to repeat the investigation, would I obtain the same results?
- How do my results compare with those of others carrying out the same investigation?

'So what' type questions:

- What does this tell me about food hygiene in the kitchen?
- What does this tell me about storing food in the fridge?
- Does this have any implications for hospitals?
- Are there other organisms around in my kitchen that I can't see?

The experiment might also have raised other questions in your mind which are not as easy (or are even impossible) to answer by experimental means, such as

- Why are there so many fungal particles in the air?
- How do fungal particles survive in the air?
- Do fungi fulfil any useful purpose?
- How long ago did fungi appear on Earth?
- What would have happened if fungi had never evolved on Earth?

Doubtless, you thought of questions — and hence potential investigations — that are not listed above. Thinking of questions about experimental results and observations may lead you to design further investigations and make new discoveries, just as Pasteur did.

Activity 2.2

At relevant points throughout the book we will remind you to add definitions of appropriate biological terms to your glossary. If you find it impossible to describe a particular term in your own words, you can of course check it in the course *Glossary*. However, unless you are really stuck, we would advise you not to do this until you reach the end of the block. This is for several reasons.

- As we said in the notes on this activity, one of the reasons for compiling a personal glossary is that thinking about the meaning of new terms will help you to understand and remember them. Copying a definition from the course *Glossary* is unlikely to help you to understand or remember a new concept.
- If you look at the course *Glossary* when a term is first introduced, you may not fully understand the glossary entry as some of the terms are refined later in the block (or sometimes, in later blocks).
- If you leave the checking until the end of the block, you will get a better impression of how you have done overall and whether you have improved as you studied the block.

When you reach the end of the block, and you have completed your personal glossary, we will ask you to check it and to compare some of your entries with those given in the course *Glossary*.

Activity 3.1

(a) There are very few actual mistakes in the description. 'Growth 1 and growth 2' are generally written 'growth I and growth II' and 'mtophase' should have been spelt 'interphase'.

(b) Perhaps the first criticism to be made is that the writer seems to assume that the reader knows what is meant by the term 'cell cycle' and therefore hardly *explains* it at all.

The phrase 'takes different amounts of time' is rather vague. If anything is to be written about how long the cell cycle takes then there needs to be more detail than this. An alternative approach is simply to omit all reference to duration of the cell cycle.

The writer could have done a lot to help the reader by re-thinking the *order* in which points are raised. For instance, replication — which takes place between growth I and growth II — is rather unhelpfully introduced right at the end. Generally speaking, if a process consists of a series of events which invariably take place in a particular sequence then it is probably best to describe the process by following this sequence.

Note that, in this case, particular care has to be exercised to distinguish between 'cell division' taken to mean mitosis plus growth of the cell membrane across the middle of the cell and 'cell division' taken to mean the *actual* separation of the parent cell into two progeny cells by the growth of this cell membrane. To emphasize the nature of this potential confusion, you will come across phrases such as 'mitotic cell division' (although mitosis is always followed by cell division). Slightly different uses of the same term or phrase are regrettably quite common in biology.

(c) Here is our attempt. Of course, yours is bound to be somewhat different. However, there is no reason to suppose that it isn't just as good.

> The cell cycle is the alternation of cell growth and division giving rise to successive generations of progeny cells. There is great variation in the total duration of the cell cycle and in the durations of different parts of it. The cycle consists of two parts — interphase and cell division. Interphase comprises two growth phases — growth I and growth II — separated by replication of the cell's DNA. Cell division consists of mitosis in which a copy of each DNA molecule goes to each end of the cell, and actual division of the cell by growth of a new cell membrane across its middle.

Note that we have used what is sometimes called a 'top down' approach here. First, an overview is given of the entire cell cycle. Second, it is pointed out that the cell cycle consists of two parts. Third, these two parts are then described in more detail in the order in which they occur.

Activity 3.2

Figures 3.2.1 and 3.2.2 are two possible diagrams. Figure 3.2.1 is a useful diagram because it puts the words 'prophase', 'metaphase', 'anaphase' and 'telophase' in the right order and links them with sketches showing what happens during each phase. This diagram is thus very complete in its visual description of the process and the order of the phases.

Figure 3.2.2 is also a useful diagram because it makes the relationship between mitosis and the rest of the cell cycle very clear. In addition, it illustrates the passage of time. (Certain phases take longer than others. We have shown their approximate *relative* durations for interest only. You were not given enough information to enable you to show these differences in your diagram.)

Your diagram is unlikely to be identical to either of ours, but does it help you to visualize the order in which the phases of mitosis take place?

Another thing which you could do to help you to remember the order of the phases is to use a mnemonic, much as we used 'BODMAS' in Block 1 to remember the order of operations in arithmetic. 'PMAT' is not very promising, but you could perhaps assign a different word to each letter so as to form a sentence. Something like 'Phone me any time'. (You can probably think of something more memorable!) Does this help?

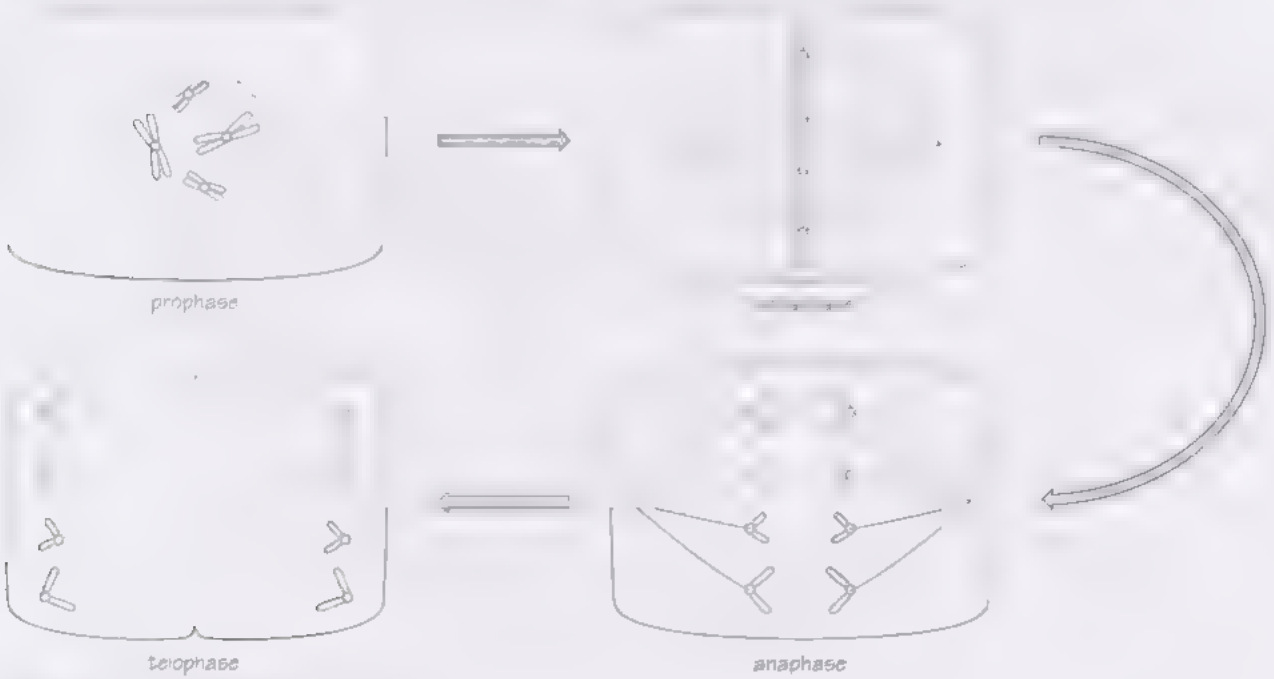

Figure 3.2.1 A flow diagram of mitosis.

Figure 3.2.2 A diagram showing mitosis within the cell cycle

Activity 4.1

(a) When you first thought about classifying the 13 animals, you might have come up with a number of ways of grouping them — for instance, those that have fur or feathers and those that don't. This would be a perfectly valid way of grouping the animals, but might leave you with some fairly diverse animals in the same group — for instance, the salmon and the ladybird would be in the same group using this scheme, although they have little else in common. From a biological point of view, therefore, the scheme is not very useful. The key to constructing a natural classification scheme is to identify some *fundamental* characteristics which allow us to group organisms that share those characteristics: hopefully this will allow us to avoid the problem of grouping together dissimilar organisms, like salmon and ladybirds, on the basis of *superficial* similarities. The characteristics listed in Table 4.1.1 are a few of the fundamental characteristics used by biologists to classify animals.

(b) See Table 4.1.2.

(c) To construct a natural classification you would group the animals according to their shared characteristics. All of the animals can move around, so all must be grouped together in an overall group 'animals that can move around'. Within this group we need to look for features that are shared by some animals but distinguish them from others. The type of support structure used by the animal — the hard parts or skeleton — is one such feature. So our completed grouping might look like Table 4.1.3.

This classification is based on the fact that the members of each group share important characteristics which are different to those of any other group. This identification of similarities and differences is the basic procedure by which any classification is carried out. In fact, these groupings are the basis of part of the natural classification scheme used by biologists. It might seem surprising that the salmon and the blue tit are in the same group, but biologists consider the type of hard parts, or skeleton, of an animal to be a much more fundamental distinguishing feature than, say, the type of body covering. The four groups identified on the basis of their hard parts are representative of four of the major groups or 'phyla' in the animal kingdom, which are introduced later in this section. (You may be interested to know that these groups are called, respectively, chordates, arthropods, cnidarians and molluscs — but you do NOT need to remember these names!)

Table 4.1.2 Completed version of Table 4.1.1 Characteristics of some animals.

	Internal skeleton	Jointed external skeleton	No obvious hard parts	Simple external shell	Ability to move around
tiger	✓				✓
Atlantic salmon	✓				✓
blue tit	✓				✓
garden snail				✓	✓
two-spot ladybird		✓			✓
lobster		✓			✓
donkey	✓				✓
elephant seal	✓				✓
Portuguese man-o'-war jelly fish			✓		✓
whelk				✓	✓
peafowl	✓				✓
strawberry frog	✓				✓
water spider		✓			✓

Table 4.1.3 Classification of 13 animals

	Animals that can move around		
Animals with an internal skeleton	Animals with a jointed external skeleton	Animals with no obvious hard parts	Animals with a simple external shell
tiger	two-spot ladybird	Portuguese man-o'-war jelly fish	garden snail
Atlantic salmon	lobster		whelk
blue tit	water spider		
donkey			
elephant seal			
peafowl			
strawberry frog			

Activity 4.2

(a) The gorilla's scientific label is *Gorilla gorilla*. (Occasionally an organism's (un-italicized) common name in a particular language is the same as the (italicized) scientific label of either its genus or its species. The gorilla's scientific label is doubly unusual in that its common name is used for both genus and species. Incidentally, the greatly endangered mountain gorilla is a subspecies whose full scientific name is *Gorilla gorilla beringei* whereas that of the (lowland) gorilla is *Gorilla gorilla gorilla*!). The gorilla is member of the class Mammalia, the order Primates and the family Pongidae.

(b) All we can say is that it belongs to the genus *Pan*. There are two species of chimpanzee, the common chimpanzee (*P. troglodytes*) and the pygmy chimpanzee or bonobo (*P. paniscus*). The question does not specify which is intended

(c) The slender loris and the lesser bushbaby (iv) are most closely related, as they are members of the same family (Lorisidae) within the suborder Prosimii. The aye-aye and the siamang (i) are the least closely related, as they are in different suborders (Prosimii and Anthropoidea respectively).

The common marmoset and the Japanese macaque (ii) and the red howler monkey and the golden lion tamarin (iii) are each members of different families within the same suborder (Anthropoidea). (In fact, since both the red howler monkey and the golden lion tamarin (iii) are New World monkeys they will be more closely related than the common marmoset and the Japanese macaque, one of which is a New World monkey while the other is an Old World monkey.)

(d) On the basis of the information in Table 4.2.1, the family Hominidae could be equally closely related to each of the other five families in the suborder Anthropoidea. (In fact, the great ape family (Pongidae) is generally regarded as closest to the human family. The gibbon family (Hylobatidae) is closest to (humans + great apes) and the Old World monkey family (Cercopithecidae) is closest to (gibbons + (humans + great apes)). However, there is increasing evidence that the chimpanzee species are more closely related to humans than they are to gorillas. This suggests that the distinction between great apes and humans is an artificial one and that all the great apes *and* humans should be classed within a single family

(e) Figure 4.2.1 shows how the human species is classified scientifically.

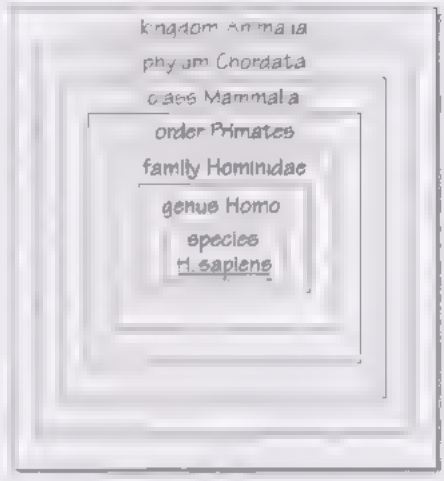

Figure 4.2.1 Scientific classification of the human species

Activity 5.1

(a) The three beliefs are that: (1) the greatest biodiversity on Earth is to be found in tropical rainforests; (2) the greatest biodiversity in the oceans is to be found in coral reefs; and (3) biodiversity decreases away from the tropics on both land and in the ocean.

(b) The article reports recent research which suggests that the maximum biodiversity on Earth may be found in the bathyal regions of the oceans (i.e. at depths of 1 000–3 000 m) away from the tropics.

(c) The high levels of biodiversity in the oceans can be attributed largely to nematode worms, which are relatively poorly known, as there are so few taxonomists studying them. There are possibly tens of millions of marine species of nematode, and up to 100 million species altogether (whereas, according to Box 5.1 of Block 4, just 12 000 of them have been fully described). The article confirms that the previous estimate of the number of species on Earth was 30 million and points out that nematodes might therefore account for about three-quarters of the new (much higher) estimate.

Note that in this activity we encouraged you to read the questions carefully before studying the article in detail. As the course progresses you will be asked to extract increasingly specialized information from increasingly complex material. It is essential that you are clear about what you are looking for before you start. This is where reading the questions carefully first helps enormously.

Similarly, many students find it helpful to read TMA questions carefully before studying the relevant course materials. They can then extract the necessary

information as they go along. Other students prefer to study a whole block before looking at the TMA questions on it. What do you think? It might be worth discussing this with other students at your study centre, or with your tutor. There is no right or wrong answer!

Activity 6.1

One possible diagram shown in Figure 6.1.1. This is a flow diagram which shows clearly the order in which the different events occur.

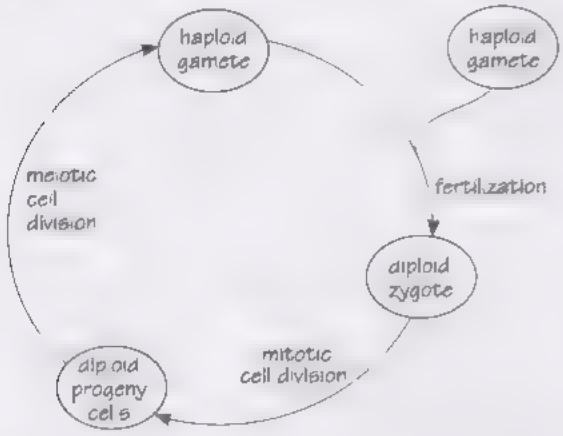

Figure 6.1.1 A flow diagram showing the events in sexual reproduction

If you have found that the diagram-drawing activities in this block help you to understand and remember important ideas, remember that you can represent text as diagrams in your own notes even when this is not explicitly suggested as part of an activity.

Activity 6.2

Table 6.2.1 compares and contrasts the two forms of reproduction. Note that if you were asked for a piece of writing comparing and contrasting sexual and asexual reproduction, producing such a table would be an excellent early stage in the planning process.

Activity 7.1

Each section of the activity has its own summary (which you can print), with that for Section 7 providing a brief summary of the entire activity. The paragraphs that follow provide a rather fuller overall summary, which you may find especially useful when you come to review Section 7 of this block before you move on to higher level studies. Note that various terms have been emboldened so that they stand out. You do not need to remember all of them.

An **ecosystem** is a **biological community** together with the **physical environment** which it occupies; a biological community comprises the species which interact with one another. Oak woodland is an example of a particularly complex ecosystem in that it supports a very large number of species. The 'Ecological chains' activity gives you an opportunity to discover some of the principles that apply to all ecosystems through investigating aspects of the oak woodland ecosystem.

Food chains are nutritional sequences. This part of the activity concentrates on one particular food chain: oak (an **autotroph**) → winter moth caterpillar (a **herbivore**) → great tit (a **first carnivore**, i.e. one that feeds on herbivores) → sparrowhawk (a **second or higher carnivore**, i.e. one that feeds on other carnivores). Autotrophs, herbivores and carnivores represent different **trophic levels** within a food chain.

Any species that depends on another as an important source of food during breeding must ensure that it times its breeding to make best use of that other species. For example, winter moth caterpillars must emerge when young oak leaves are available since they cannot cope with older tannin-rich oak leaves, and tits must hatch when caterpillars are around.

Of course, many herbivores and most carnivores feed on more than one other species — and are themselves preyed upon by more than one other species. In addition, **detritivores** and **decomposers** (which are not regarded as a trophic level) physically and chemically break down the dead bodies of organisms that have not been consumed either by organisms at the next trophic level or by **parasites**. Thus, a simple food chain is usually just part of a far more complex **food web**. A species may occupy different trophic levels in different food chains within a food web; for example, tits act as herbivores when they consume seeds and act as first carnivores when they consume caterpillars.

Table 6.2.1 A comparison of asexual and sexual reproduction.

Asexual reproduction	Sexual reproduction
Produces offspring.	Produces offspring.
Offspring are smaller than parent, and must grow.	Offspring are smaller than parents, and must grow.
One parent only.	Two parents.
No gametes are produced	Gametes are produced. These are haploid. Nuclei of two gametes fuse (fertilization) to form a diploid zygote.
Meiosis absent.	Meiosis present at some stage in the life cycle.
DNA of offspring identical to that of parent.	Part of the offspring DNA is a copy of some of the DNA of one parent, the remainder is a copy of some of the DNA of the other parent.
Offspring identical to parent.	Offspring not identical to either parent.
Commonly occurs in plants, less complex animals and micro-organisms. Absent in more complex animals.	Occurs in the majority of plants and animal species.
Often results in the rapid production of large numbers of offspring.	Less rapid increase in numbers.

When the number of great tits and winter moth caterpillars required to raise one sparrowhawk is investigated in detail, a **pyramid of numbers** emerges in which smaller numbers of animals are found in each successive trophic level. There is, however, a dilemma at the lowest trophic level in this food chain: is it more relevant to count the enormous number of oak leaves needed to raise one sparrowhawk or the very much smaller number of oak trees? This problem is overcome by using a **pyramid of energy**, which shows that the amount of energy flowing through each trophic level in a food chain in unit time decreases as we progress from autotrophs through to higher carnivores.

The Sun is the ultimate source of energy in the oak woodland ecosystem. However, only about 1% of the **solar energy** falling on plants is captured by **photosynthesis**. The energy which is captured is referred to as the **gross primary productivity** (or **production**) (**GPP**) of the ecosystem. This energy has two possible fates: it is either expended in **respiration** in order to maintain the plants' metabolism or it is stored as chemical energy in the plants' **biomass**. Biomass is often expressed in terms of its chemical energy content rather than in units of mass. Addition to the plants' biomass is referred to as the **net primary productivity** (or **production**) (**NPP**) of the ecosystem. Autotroph biomass might increase over time, or it might decrease because NPP is unable to keep pace with consumption by herbivores. Alternatively, it might remain at a more-or-less constant level; this situation would apply in an ecosystem that had reached, and been allowed to remain in, a steady state

Both GPP and NPP are generally expressed in units of energy per unit time and (usually) per unit area, and they are related by the equation:

GPP = energy used in plant respiration + NPP

Some plant biomass is **consumed** by herbivores. Part of this consumed biomass is **assimilated** into herbivores' bodies and the rest is generally lost as **faeces**. In addition, some birds of prey also produce indigestible pellets of feathers, bones, etc from the other end. The energy stored in the food assimilated by herbivores may be used for **respiration** in order to maintain their metabolism or it may be stored as herbivore **biomass**.

Again in units of energy per unit time and (usually) per unit area

biomass consumed =
energy assimilated + energy lost in faeces, etc.

energy assimilated =
energy used in respiration + increase in biomass

Exactly the same principles apply to consumption of herbivores by first carnivores and also to consumption of first carnivores by higher carnivores (and, indeed, to partial 'consumption' of living organisms by parasites) Comparatively little of the biomass of one trophic level ends up as biomass in the next trophic level.

Note that there may be no net increase in biomass at a particular trophic level during a particular time interval because all the assimilated energy not used for respiration might be utilized by other species (parasites, detritivores, decomposers and members of the next-highest trophic level).

Detritivores and decomposers between them break down the dead bodies of all organisms (i.e. plants, herbivores, carnivores, parasites, detritivores and decomposers) and thereby obtain energy for their own respiration and increase in biomass. Of course, in feeding on the faeces produced by organisms at one trophic level, detritivores and decomposers are also feeding indirectly on the biomass produced by organisms at the next lowest trophic level (i.e. herbivore faeces is largely unassimilated plant biomass — along with gut bacteria, gut wall cells, digestive enzymes, etc.). As a consequence, all the energy captured by photosynthesis in an ecosystem is ultimately released through respiration by one organism or another (with the possible exception of any that might be lost through combustion in the short term or incorporated into the geochemical part of the carbon cycle in the long term).

Activity 7.2

Compare your answer with the one below, written by a student: (The terms you were asked to include are printed in italics.)

An *ecosystem* is a set of organisms linked by flows of energy and materials.

Energy enters the ecosystem in the form of *solar energy*, captured during *photosynthesis* by *autotrophic* organisms such as plants. These autotrophs form the lowest *trophic level* of an ecosystem.

The energy captured by autotrophs during photosynthesis is known as the *gross primary productivity* of the ecosystem. Some of the energy is lost when the plants *respire*, but the rest goes to make plant material or *biomass*. The amount of plant biomass produced is known as the *net primary productivity* of the system.

Plant biomass may then be consumed by *heterotrophic* organisms; that is, organisms that do not use solar energy directly but gain their materials and energy by consuming other organisms.* Plant-eating animals, called *herbivores*, are heterotrophs and constitute a higher trophic level. The transfer of materials and energy between organisms in different trophic levels is the basis of a *food chain*. The heterotrophic organisms are able to *assimilate* some of the plant material, and the rest is discarded as *faeces*. Assimilated food is either used to build animal biomass, or is used in respiration, with the energy then being lost from the ecosystem

Energy continues to flow through an ecosystem into further trophic levels of the food chain, consisting of the primary and higher *carnivores*, which consume other animals and are therefore also heterotrophs. Dead plant and animal material, and animal faeces, may be consumed by yet other heterotrophs — *decomposers* and *detritivores*.

The complex system involving many such transfers of energy and materials creates a *food web*. Energy is finally lost from the ecosystem through respiration of detritivores and decomposers. (*276 words*)

*You might have made additional points, for example, that plant biomass may be burned (e.g. in forest fires) or may enter the rock cycle as part of an organic rock (such as coal) (recall your study of Block 2, Section 8, on the carbon cycle), in such cases the materials and energy are removed from the ecosystem.

How does your answer compare with this student's? Obviously they will be different, but they should convey the same overall meaning. If they don't, is this because you have misunderstood the meaning of one of the new terms? Look it up in the course *Glossary* if necessary.

If you have correctly understood all the terms, have you used them unambiguously and explained their meaning where necessary? Look at your own writing critically, in much the same way as you looked at someone else's writing critically in Activity 3.1.

Finally, look critically at the structure of your piece of writing. Did you try to order the terms in a logical fashion so that they fitted in with your plan, or did you just take them in the order they were listed in the question — alphabetically? Here is the plan from the student who wrote the answer above:

Introduction: ecosystem

Initial energy input: solar energy, photosynthesis, autotroph, gross primary productivity

First stage (plant productivity) biomass, respiration, net primary productivity, trophic level

Next stage: heterotroph, herbivore, food chain, assimilate, faeces

Next stage: carnivore, decomposer, detritivore

Summary: food web

This student started by grouping the terms into what she thought were related topics, and then tried to structure her account around that list. As you can see, she had to move a few of the terms to construct her final account, but the initial ordered list gave her a good structure to build on. In fact, she ended up by writing a paragraph around each group of terms. How did you structure your account?

As the course progresses, we will be encouraging you to be more self-critical of your own work.

Activity 8.1

Task 1

Holly leaf miners will emerge from some of the mines in the leaves in late May. However, many will die — or have already died — from various causes of mortality. Using certain features of the mines, it is usually possible to identify those from which holly leaf miners emerged successfully or — where they didn't — the particular cause of mortality. Blue tit predation is one of the easier causes to identify. All this will be explained fully when it is time to carry out the main practical work on the holly leaf mine, if you decide to study Block 9.

Task 2

We cannot, of course, provide definitive answers to any of the questions posed. What follows are comments on some of the issues that you would need to consider if you were to try to answer the questions practically. If you are relatively new to practical science, you should be pleased with yourself if you thought of even a few of these issues.

(a) You can't examine *all* the leaves to determine what percentage have been mined, even on a single holly bush (unless it is *very* small). You therefore have to examine a *sample* of leaves. But biological material is intrinsically variable. For example, some leaves are mined and others aren't. Two issues therefore arise immediately: How can you ensure that the leaves in your sample are *representative* of the entire population of leaves (for instance, on your particular holly)? How *large* should your sample be? To ensure a representative sample, you need to examine leaves at random, without looking first to see if the leaf has been mined. Otherwise there is a danger of inadvertently introducing a bias to your sample (for instance, by allowing yourself to be particularly 'drawn' to mined leaves). The more leaves you examine, the more representative your sample is likely to be. On the other hand, examining a lot of leaves is rather time-consuming and spending a great deal of time sampling might prevent you carrying out other important parts of an investigation or other 'follow-up' investigations.

Examining from a few dozen to about 100 leaves is probably adequate for our present purposes. To avoid introducing bias, it might be best to choose — as randomly as possible (i.e. without looking at the leaves before choosing) — several branches from different parts of the holly and then examine *all* the leaves on those branches, recording each leaf as either 'mined' or 'not mined'.

(b) The same principles as discussed in (a) apply here. You need to examine an adequate number of mined leaves in order to work out the percentage that show signs of blue tit predation. Of course, to give a reasonable sample size, this might involve examining rather more leaves in total than in (a). It might be possible to combine (a) and (b) by choosing branches at random, examining *all* the leaves on those branches and scoring the leaves as 'mined with evidence of blue tit predation', 'mined without evidence of blue tit predation' and 'not mined'.

(c) In addition to the principles discussed under (a) and (b) above, you need to think about such matters as what heights above the ground are appropriate, how accurately do you need to know the height, how would you reach the higher branches safely, how would you determine the prevailing wind direction (possibly in rather dense vegetation)?

Another consideration is how great any difference (e.g. between level of predation on the windward side compared to the sheltered side) has to be before it can be regarded as *significant*, rather than attributable to (say) choosing one particular branch rather than another.

Activity 9.1

In this, the first part of the Galapagos DVD-multimedia activity, you explored the concept of *adaptation*. An adaptation is some feature of an organism that suits it to its way of life by increasing the chance that it will survive and reproduce in the particular environment in which it lives. An individual is adapted now because of the effects of natural selection on its species in the past. Many of the species in the Galapagos show a relationship between lifestyle, diet and habitat. For example, beak size and shape varies among the different species of Darwin's finches and is highly dependent on the birds' diet and feeding habits, which in turn are related to the habitat occupied by the birds.

You have seen that the Galapagos Islands are very isolated and are volcanic in origin. They provide a unique mix of temperate and tropical environments

because, despite being on the Equator, their climate is affected by cool sea currents. The species of animals and plants that originally colonized the islands adapted to the new conditions that they found and eventually evolved into new species. As a result, many of the species found in the Galapagos are endemic to the islands and some are endemic to a single island. The Galapagos Islands are of particular interest to biologists because, so far, they have been relatively unspoilt by human activity.

Activity 11.1

(a) See Table 11.1.2.

(b) See Table 11.1.2. Bird 4 left the most fledglings (8) and has a relative fitness of 1.000. The relative fitness of any of the other birds is calculated by dividing the number of fledglings they leave by 8. For instance, the relative fitness of bird 3, which leaves 4 fledglings, is:

$$\frac{4}{8} = 0.500 .$$

(c) There are three components of fitness: survival (how many winters the birds survived), clutch size (number of eggs each year), and number of fledglings each year.

(d) Survival is not a very good indicator of relative fitness. The two longest survivors (birds 4 and 6) had high relative fitnesses, but so did birds 2, 7 and 10, who lived for only two years.

(e) Clutch size in year 1 is not a good indicator of relative fitness. Birds 1, 5 and 10, for example, had large clutches in year 1, but had low relative fitnesses. Bird 4, which has the highest relative fitness, had the smallest clutch size in year 1.

(f) The values in column 11 do not reflect the true relative fitnesses of the ten birds, because these data do not contain any information about the reproductive success of the fledglings produced by the ten birds.

This exercise should have served to illustrate two points about the measurement of fitness:

(i) Partial fitness measures, such as clutch size in a single year, can be very poor indicators of true fitness. Even survival is a poor indicator of fitness.

(ii) Accurate estimates of fitness require the collection of data for many measures of partial fitness. The more such measures we have, the more accurate our final estimate of fitness is likely to be.

The data in Table 11.1.2 also emphasize that fitness results from trade-offs during an individual's life. In this instance, we can see how, for bird 4, reproduction in the first year is traded-off against survival. She had the smallest clutch size in year 1 but survived for three years and ended up with the highest relative fitness.

Activity 11.2

(a) The eight factors mentioned in the text that influence clutch size are: (i) inheritance, (ii) egg size, (iii) food supply after hatching, (iv) density of the population, (v) age of bird, (vi) future reproduction, (vii) weather and food supply, and (viii) density of oak trees.

(b) A trade-off occurs when there are two or more factors which cannot all be optimized at the same time. If one improves, this has a detrimental effect on another. The best possible outcome is therefore to reach a compromise such that the combination of factors is as beneficial as possible in the circumstances. A dictionary definition of 'to trade-off' is 'to barter' and the analogy with motor cars given in Section 8 may be helpful. The definition in the Course Glossary refers to 'the balance necessarily struck by an organism between competing demands for limited resources'.

A possible answer is as follows:

> There is a trade-off between egg size and clutch size; as egg size increases so clutch size decreases. A few large eggs might possibly produce a few fledglings, many very small eggs will possibly produce none. However, the trade-off results in an intermediate number of intermediate-sized eggs which would produce more fledglings than either extreme.

Table 11.1.2 Complete version of Table 11.1.1 Measures of reproductive success and fitness for a hypothetical population of 10 female great tits which survived their first winter (Winter 1).

Bird	Breeding success in Year 1		Fate in Winter 2	Breeding success in Year 2		Fate in Winter 3	Breeding success in Year 3		Total number of fledglings	Relative fitness (1 sig. fig.)
	No. of eggs	No. of fledglings		No. of eggs	No. of fledglings		No. of eggs	No. of fledglings		
1	14	3	dies	–	–	–	–	–	3	0.375
2	15	2	survives	16	3	dies	–	–	5	0.625
3	16	4	dies	–	–	–	–	–	4	0.500
4	10	2	survives	12	3	survives	11	3	8	1.000
5	17	4	dies	–	–	–	–	–	4	0.500
6	11	3	survives	12	2	survives	12	1	6	0.750
7	12	3	survives	14	2	dies	–	–	5	0.625
8	14	4	dies	–	–	–	–	–	4	0.500
9	12	0	dies	–	–	–	–	–	0	0.000
10	16	3	survives	17	4	dies	–	–	7	0.875

Note how well this explanation of the trade-off between egg size and clutch size illustrates the general principle of a trade-off. You may have chosen a different example. Does your explanation make the general principle clear? If not, this could be because you picked a more difficult example or it could be that you need to write your explanation more clearly. Once again, you are developing here the skill of being self-critical. Be realistic, but don't be too hard on yourself at this stage. We will give you a lot more help as the course progresses.

Activity 12.1

(a) Only you can decide how effective producing a glossary has been *for you*. However, many students (and tutors!) find it very helpful to express a concept in their own words, to make a note of it for future reference, and to extend their understanding of it by applying it to a new situation. In the next two blocks we will suggest that you produce different kinds of glossary that are particularly appropriate for the subject matter of those blocks.

(b) Answering from memory is a good way of checking whether you have absorbed information from the course material, and it is worth doing this periodically. In the real world, it is generally more important that you be able to look up information and use it appropriately, and this is what you do when answering TMA questions. However, for courses you may take in the future, which may have a traditional exam, a certain amount of recall ability will be required, so practising this skill is useful preparation for higher level study.

(c) The scientific terms you used in your own writing in Activity 7.2 included food chain, food web, trophic level, biomass, autotroph, heterotroph, etc. From the article in Activity 5.1 you may have picked out nematodes, biological resources, sediments, continental shelves, bathyal regions, biodiversity, vertebrates, organisms, taxonomists, etc. Since this article was written by a scientist for other scientists, the author assumed that his readers were familiar with some of the terms, and used them without explanation. However, for other terms such as 'nematode' and 'bathyal region', which would not be familiar to the average reader, the author has been careful to include a phrase that indicates their meaning. Your task was slightly different in that you were required 'to show a good understanding' of the terms; in some cases you may have been able to do this by using them correctly in context, but in other cases an explanatory phrase or a more formal definition might have been appropriate.

As you practice writing as a scientist, you will have the benefit of advice from your tutor on their perception of your writing. What follows is an example of a student–tutor telephone conversation about the student's writing. It was initiated by a student who wanted to sort out how to improve her marks on an assignment.

Student: I really worry about this business of being concise. I wrote a first answer that was too long, and so I cut some things out, and then when you sent my TMA back, you told me I should have included what I had cut out. The trouble was I just sat down and wrote, and I said too much, and then when I tried to trim it down, I chose the wrong things to cut. Would I lose many marks if I went over the word limit?

Tutor: Not many — but I think you might have highlighted your problem: if you just sat down to write, does that mean you didn't take time to plan first?

Student: Well I know I should do that, but it seemed pretty obvious what was wanted, and so I just started straight in.

Tutor: I think it would help you to highlight key words in the question, and then to make a few notes of what you think is relevant to each part. I often use a large sheet of paper for this, and then I use different colour highlighters for ideas I want to put together, and I number things to show the order I want to tackle them in the answer.

Student: The trouble is that now I'm using a word processor it's just so easy to type out the answer straight away, because I can always change things around later if I want to.

Tutor: That's true — and I have to confess I don't always follow my own good advice, but I'd still recommend thinking and planning *before* you launch in. Another thing: you write really fluently. Have you any tips for other students about that?

Student: I find that easy. I suppose I did plenty of writing in school, though that's a while ago. I remember my English teacher once said my use of links between one idea and the next was very good. But I like what you said on the TMA feedback form about signposting.

Tutor: Yes. It makes a big difference if you begin a paragraph with a general statement of what will be in that paragraph, and then you can go on to discuss, describe specific examples, bring up evidence to support a point of view, or whatever it is you want to achieve in that paragraph.

Student: So what I should be trying to do is:

- plan my written answers;
- tackle the ideas in a logical sequence;
- introduce an idea in general terms before going into details;
- make links from one idea to the next.

Is there anything else?

Tutor: Sometimes a summary at the end, exactly as you've just done, is really useful. I look forward to your next assignment!

Of course, each of us evolves our own style of writing, and you will have noticed a variety of styles in the course material, which is written by many different authors. Like any skill, you will improve your written work by practice, by critically assessing your efforts, by obtaining feedback (from your tutor), and then by thinking about how *you* would like to change it, followed by trying again.

Objectives for Block 4

The objectives state what you should understand and what you should be able to do after studying the block.

The numbers of questions and activities that test each objective are given in italics. In the margin next to some objectives are references to *The Sciences Good Study Guide (SGSG)*, giving the chapter: section number or Maths Help (MH) number, or to DVD material, where you can find additional support.

Science content

1 Explain the meaning of, and use correctly, all the terms printed in **bold** in the text. (*All numbered questions and activities, but particularly Activities 2.2, 7.2 and 12.1*)

2 Describe how living organisms are characterized by the three attributes of life: reproduction, growth and metabolism. (*Questions 2.3 and 2.5–2.7*)

3 Distinguish between life cycle and generation time, and describe and or sketch the important features of each. (*Question 2.1*)

4 Describe the differences between, and explain the significance of, autotrophic and heterotrophic metabolism. (*Questions 2.2–2.6*)

5 Describe a typical cell in terms of three components: the nucleus containing chromosomes, the cytoplasm and the selectively permeable cell membrane. (*Questions 3.1 and 3.2*)

6 Distinguish between prokaryotic and eukaryotic cells and organisms. (*Question 3.2*)

7 Describe the cell cycle and illustrate it by means of a simple diagram. (*Questions 3.3–3.5, Activity 3.1*)

8 Describe in outline the process of mitosis. (*Questions 3.4 and 3.5; Activity 3.2*)

9 Discuss the concept of biological species. (*Activity 4.1*)

10 Explain why species are given scientific labels and use such labels correctly. (*Question 4.2*)

11 Describe in outline the classification of living organisms into three domains, one of which is divided into four kingdoms. (*Question 4.1*)

12 Describe the principles by which animals are classified with particular reference to the phylum, the genus and the species. (*Question 4.2; Activities 4.1 and 4.2*)

13 Describe what is meant by biodiversity, how it can be estimated and why it is important. (*Questions 5.1 and 5.2; Activity 5.1*)

14 Describe and compare sexual and asexual reproduction. (*Questions 6.1–6.3; Activities 6.1 and 6.2*)

15 Describe, and discuss the significance of, different life cycle strategies. (*Questions 8.2 and 8.4; Activities 7.1 and 8.1*)

16 Describe, and discuss the significance of, simple food chains and webs. (*Activity 7.1*)

17 Balance energy flow through simple food chains and webs. (*Activity 7.1*)

18 Discuss the concept of adaptation and how it relates to evolution. (Question 10.2; *Activity 9.1*)

19 Discuss the concept of trade-off in terms of different life cycle strategies, the dynamics of populations and other aspects of organisms' biology. (*Questions 8.3, 8.4 and 11.1–11.3; Activity 11.2*)

20 Describe the process of natural selection and its relationship to evolution. (*Questions 10.1–10.3 and 11.1–11.4*)

Science skills

21	Design and perform a simple scientific experiment or investigation following instructions, and interpret the results obtained. (*Activities 2.1 and 8.1*)	*SGSG* 8.3
22	Interpret scientific data presented in various ways. (*Question 8.1; Activity 11.1*)	*SGSG* 3.3.2
23	Critically assess scientific investigations performed by oneself or others. (*Questions 5.2 and 10.3; Activities 2.1 and 8.1*)	*SGSG* 8.3
24	Devise, and use, classification schemes that group similar objects and distinguish between dissimilar objects. (*Questions 4.1 and 4.2; Activities 4.1 and 4.2*)	

Communicating science skills

25	Communicate scientific information clearly in writing, using correct scientific terminology. (*Activities 3.1, 7.2 and 11.2*)	*SGSG* 9:1.5
26	Extract information from a piece of scientific writing. (*Activity 5.1*)	*SGSG* 2
27	Critically assess your own and others' scientific writing for accuracy and style. (*Activities 3.1, 7.2 and 12.1*)	*SGSG* 9.5

Mathematical skills

28	Perform simple arithmetical calculations. (*Question 5.1; Activities 2.1, 7.1 and 11.1*)	*SGSG* M1

Effective learning skills

29	Produce a glossary of scientific terms as a source of reference and to help memorize the terms. (*Activity 2.2*)	
30	Summarize important concepts and relationships in a diagram. (*Activities 3.2, 6.1 and 7.1*)	*SGSG* 3.2.4
31	Use reflection on experience to review study methods and make improvements where necessary. (*Activities 1.1 and 12.1*)	*SGSG* 1.4, and 6.5

Appendix 1 What to do if you are short of time

The five numbered columns in the table below offer advice about each activity as follows:

1 essential that you do this activity at the particular point in Book 4 where it appears;

2 important, but there is more flexibility about when you do this activity, although you should try to complete it before moving onto the next section of Book 4;

3 may not be essential if you have some background already in the topic or skill, or have found earlier, similar activities straightforward;

4 could be left until later on, or dropped altogether if you are really short of time;

The last column on the right contains additional advice about some of the activities.

Block 4 activities

Activity	Category				Comments
	1	2	3	4	
1.1			✓		
2.1				✓	
2.2			✓		
3.1			✓		
3.2			✓		
4.1			✓		
4.2			✓		
5.1		✓			
6.1			✓		
6.2			✓		
7.1	✓				Important to move through early material quickly
7.2		✓			
8.1		✓			Could be postponed until Block 9, if you decide to study this Block
9.1	✓				Important not to go beyond Part I at this stage
11.1			✓		
11.2			✓		
12.1		✓			

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Introduction to an oak woodland

Using the virtual woodland landscape and the field guides you have found and identified a number of species that occupy an oak woodland.

The species which interact with each other form a biological community.

The biological community and the physical environment it occupies is an ecosystem.

The oak tree itself can be regarded as an ecosystem It provides many different environments which a wide range of species can occupy as their habitats

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A sparrowhawk's eye view

There are complex inter-relationships within an ecosystem, but by focusing on a single species you were able to unravel some of that complexity. You were able to construct a nutritional sequence or food chain, starting with the sparrowhawk. You first found the food that the sparrowhawk predominantly eats. You repeated this process with the great tit, the food of the sparrowhawk, and completed the chain by finding that the food of the great tit is winter moth caterpillars, and these in turn eat the leaves of oak trees. The chain consists of two carnivores, a herbivore and begins, as all food chains do, with an autotroph.

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How much food to raise a brood?

Having identified the steps in a food chain, it may be possible to establish how many individuals of a particular species are needed to support those species which feed on them either directly or indirectly. Although the resulting pyramid of numbers is interesting, it must be used with caution (e.g. consider whether individual oak trees or individual oak leaves form the base of the oak - winter moth - great tit - sparrowhawk food chain). Great care needs to be taken over the collection of data to ensure that reasonably accurate averages are used when food chains are quantified.

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Energy flow

Organisms in a food chain represent sources of energy for those organisms which feed on them. Thus a food chain can be converted into an energy chain and a pyramid of numbers can be converted into a (much more useful) pyramid of energy flow. Only a tiny proportion of solar energy falling on plants is captured by photosynthesis as gross primary productivity (GPP). Of this, some is used in plant respiration and only that stored as increase in plant biomass (net primary productivity or NPP) is potentially available to herbivores. For both herbivores and carnivores,

biomass consumption = energy assimilated + energy lost in faeces
and
energy assimilated = increase in biomass + energy used in respiration.

Comparatively little of any species' biomass ends up as biomass increase in the next species in a food chain.

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Getting the timing right

A key feature in breeding success is getting the timing right. In this exercise you identified some of the key dates in the year of the oak tree. You then identified the key stages in the life cycle of the winter moth, and the blue tit. (The blue tit occupies the same position in the food chain as the great tit, both birds being taken by the sparrowhawk). Using the field guides you put durations to the key stages in the life cycles of the winter moth, the blue tit and sparrowhawk.
All these pieces of information were then used to investigate the optimal timing in the year for caterpillar egg emergence, and breeding for the blue tit and the sparrowhawk.
You found that whilst each organism acts in its own best interests, its actions often have considerable consequences for other organisms in the food chain. Finally you saw that there is difference in timing between individuals of each species, and looked at some of the implications of changes in the weather at critical times of the year, and global warming.

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Food webs

This section took a broader look at the interactions between species in the woodland. Most species are part of several interacting food chains. By looking at the tit in the food chain you saw that the sparrowhawk competes with other species for this food source. You then constructed a food web that explored a few of the many interactions in the woodland ecosystem. This system was used to classify the organisms into different classes, such as producer, consumer, herbivore and carnivore, and introduce new classes of organism such as parasites, decomposers and detritivores. Most organisms harbour smaller parasites. All organisms which avoid being consumed and die a natural death are broken down by detritivores and consumers, as are faeces and other waste. Thus, the oak wood and other ecosystems are best thought of in terms of food webs rather than food chains. The ultimate fate of all the energy captured by photosynthesis (GPP) is to be used in respiration by one of the organisms in a food web (ignoring combustion).

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Pulling it all together

The food web can be organised in terms of trophic levels. Trophic level one, the autotrophs, fix energy from the sun which is used by herbivores (trophic level 2). These are in turn consumed by primary carnivores (trophic level 3), which in their turn are consumed by secondary carnivores. At each of these levels energy consumed is either assimilated or discarded / unassimilated. That which is assimilated is either respired or becomes biomass. Discarded or unassimilated energy is utilised by decomposers and detritivores. All the energy at each level can be quantified. Parasites were excluded from this numerical analysis.

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